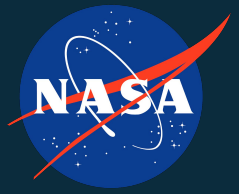
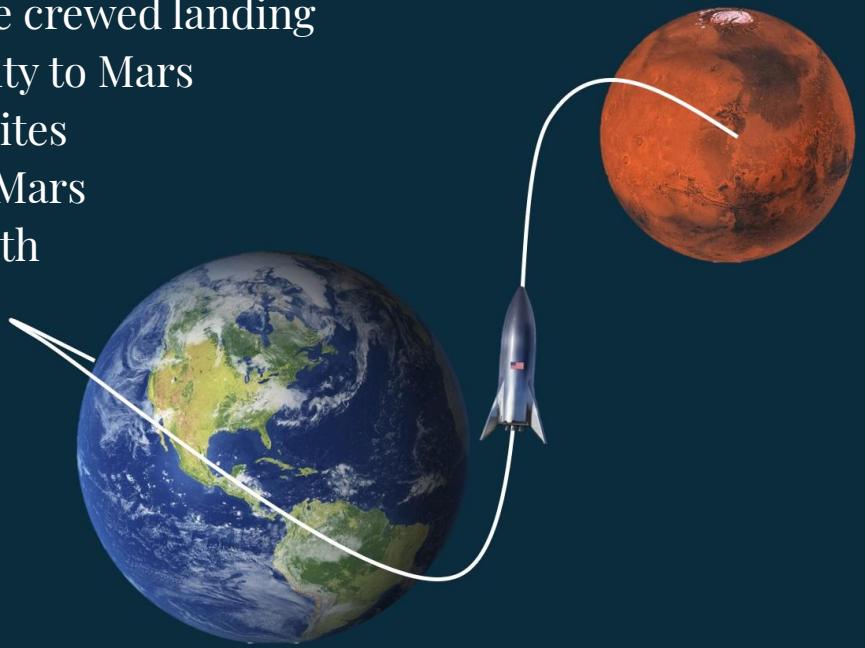


MISSION TRANSIT

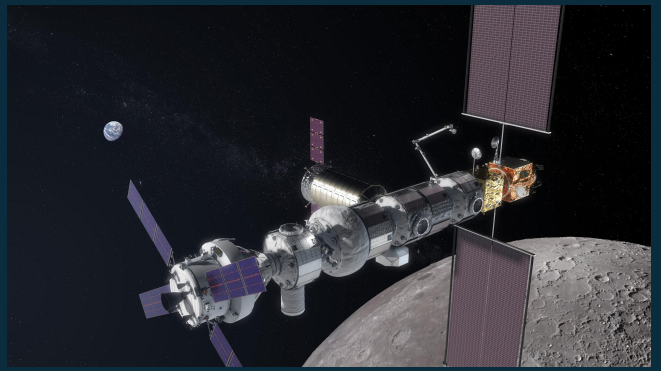
Mission Goals and Requirements

- Transport cargo to Mars before crewed landing
- Transport habitat and lab facility to Mars
- Launch communications satellites
- Safely transport astronauts to Mars
- Safely return astronauts to Earth



Team Responsibilities

- Orbital Mechanics
  - Transfer Windows
  - Delta V
  - Orbital Trajectories
  - Free Return Trajectory
    - Venus Flyby
- Mass Budget
  - Propulsion Systems
  - Launch Vehicles
    - Cargo
    - Crew
- Entry, Descent, Landing
  - Landing System
- Risks
  - Radiation
  - Health Concerns



Orbits and Trajectories Earth-Moon

Go From LEO to Lunar Gateway

- Circular Orbit Around Earth
- Elliptical Transfer Orbit
- Hyperbolic Encounter With Moon
- Near-Rectilinear Halo Orbit

$$\Delta V_1 = \left|\sqrt{\frac{3.986*10^5}{6878}} - \sqrt{(3.986*10^5)\left(\frac{2}{6878} - \frac{1}{\frac{384400+6878}{2}}\right)}\right| = 3.058$$

$$\Delta V_2 = \left|\sqrt{(3.986*10^5)\left(\frac{2}{408439} - \frac{1}{384400}\right)} - \sqrt{\frac{3.986*10^5}{404949}}\right| = 0.037$$

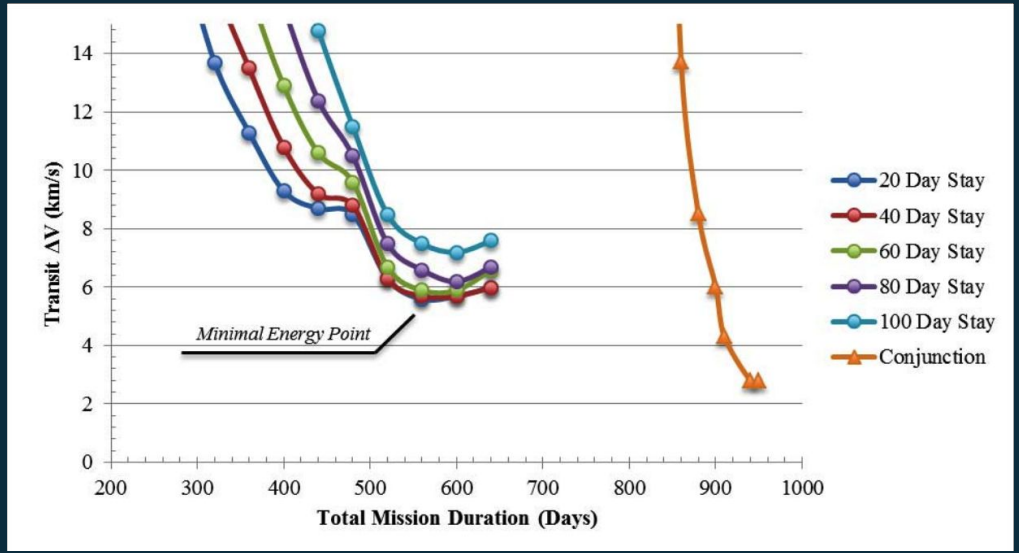
$$\Delta V_3 = \left|\sqrt{\frac{(2)(4.905*10^3)}{5307.1}} - \sqrt{\frac{4.905*10^3}{5307.1}}\right| = 0.398$$

$$\Delta V_{total} = 3.492$$

Math Necessary to Map This Transfer

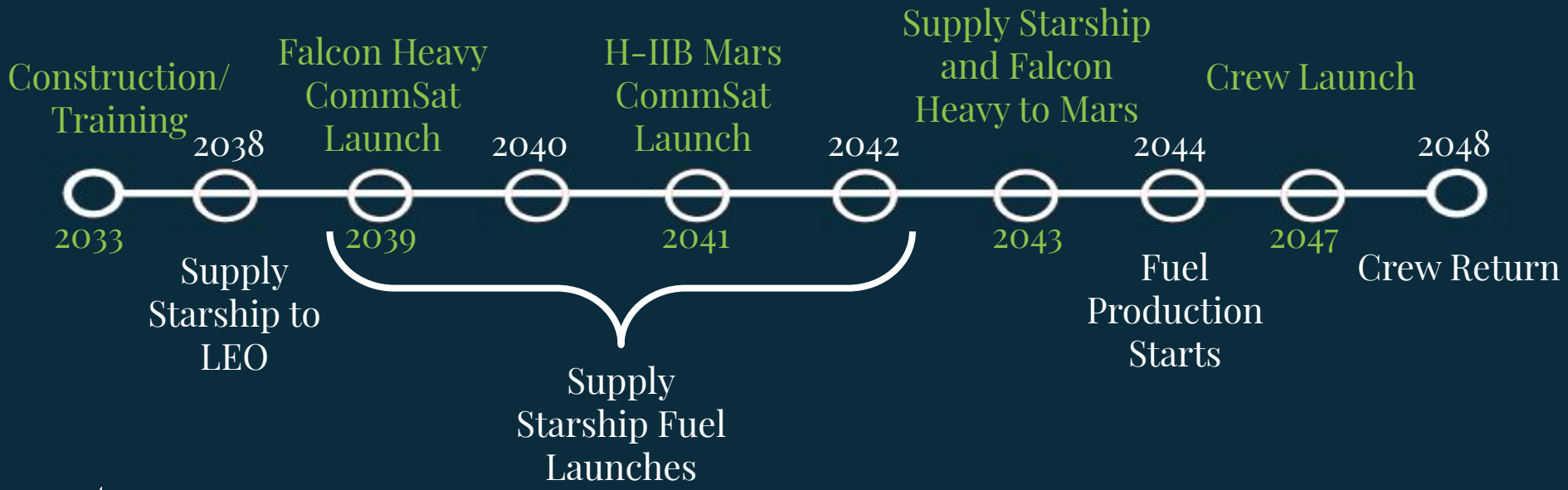
Orbits and Trajectories Earth-Mars

- Conjunction Class Trajectory Slingshot Around Venus
- EVME Free Return Trajectory
- The Return Trip will Take Advantage of an Open Hohmann Transfer Window



ΔV vs Mission Duration to Reach Mars

Con-Ops Timeline



Mass Budget & Launch Vehicles

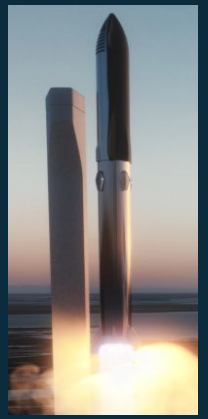



SpaceX Cargo Starship	SpaceX Falcon Heavy (1 & 2)	Mitsubishi H-IIB	SpaceX Crew Starship
Payload Total: 99,800 kg Hydrogen for fuel production Hydrogen cooling systems	Falcon Heavy 1 Payload Total: 11,355 kg Methane generator & nuclear power source JAXA robots Falcon Heavy 2 Payload Total: Relay comm. satellite: 1,500 kg	Payload Total: 665 kg Main Satellite for communications network	Payload Total: 84,240 kg Astronaut Crew (5) Scientific Payloads Life support Payloads In-Transit technology

Propulsion

Starship (SpaceX):

- Holds up to 1200 tons of propellants
- 6 Raptor Engines (3 sea-level engines and 3 vacuum engines)
  - Liquid oxygen (LOX) and methane (CH_4)



Falcon Heavy (SpaceX):

- Merlin Engines
  - Liquid oxygen (LOX) and rocket-grade kerosene
- Second Stage: Merlin Vacuum Engine

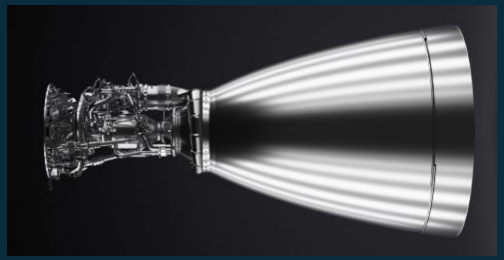
Propulsion

H-IIB (JAXA):

- Liquid hydrogen and liquid oxygen
- Liquid rocket engine (LE-5B) in the second stage

Cargo Capsule:

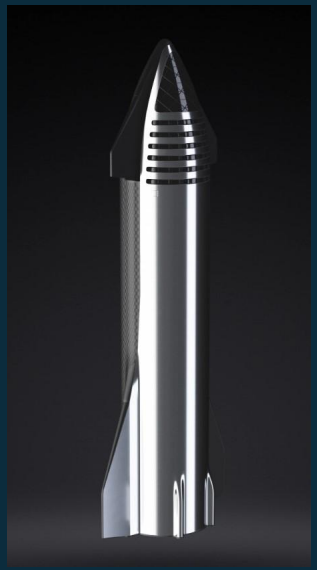
- 2 Merlin Vacuum Engines
  - Liquid oxygen and rocket-grade kerosene (RP-1)



Transit Vehicle Design

Starship (designed by SpaceX)

- Reusable
- Has the ability to carry enough storage for all of the food and water needed for the journey
- Includes life support and other necessities
    - Living quarters
    - Research
    - Recreation

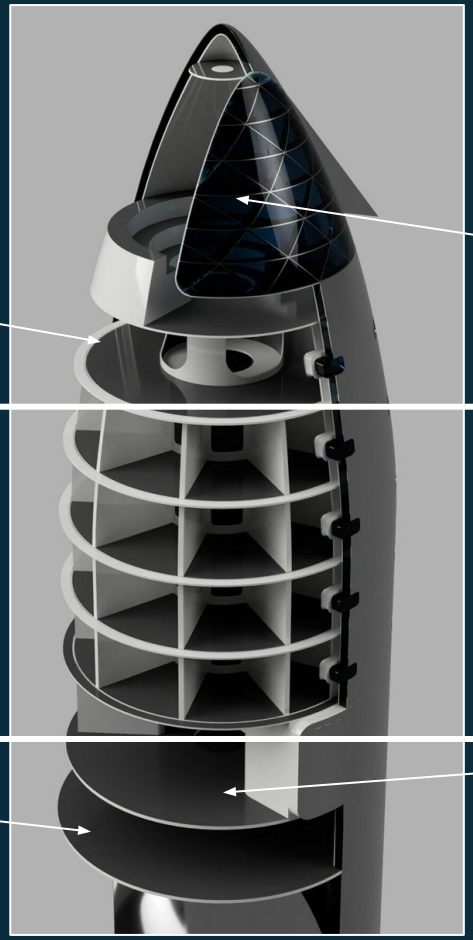


Starship

Exercise and Recreation Rooms

Crew Cabins, Dining Area, PET scanner and Research Room

Food and Water Supply

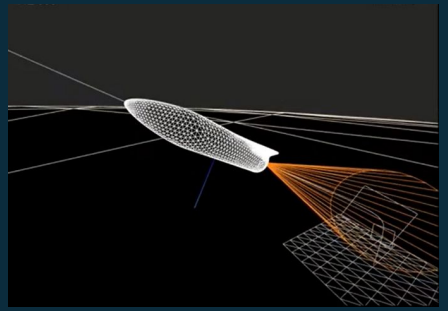


Navigation and Communications

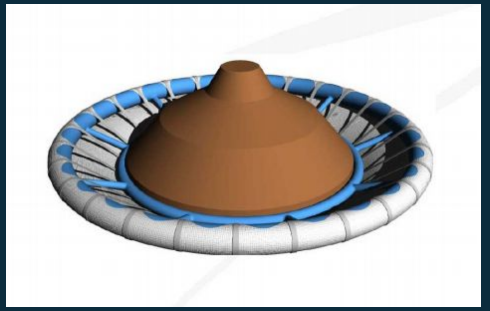
General Storage

Entry, Descent, and Landing

- Starship Landing
  - Orbital injection
  - Atmospheric aerobraking
  - Landing burn



Starship Retroburn

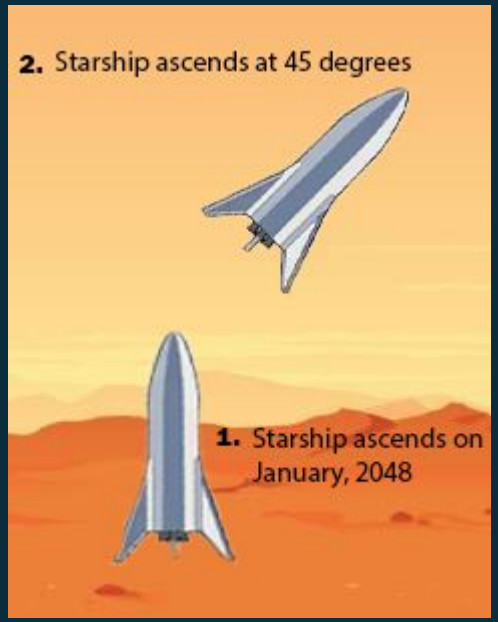


HIAD

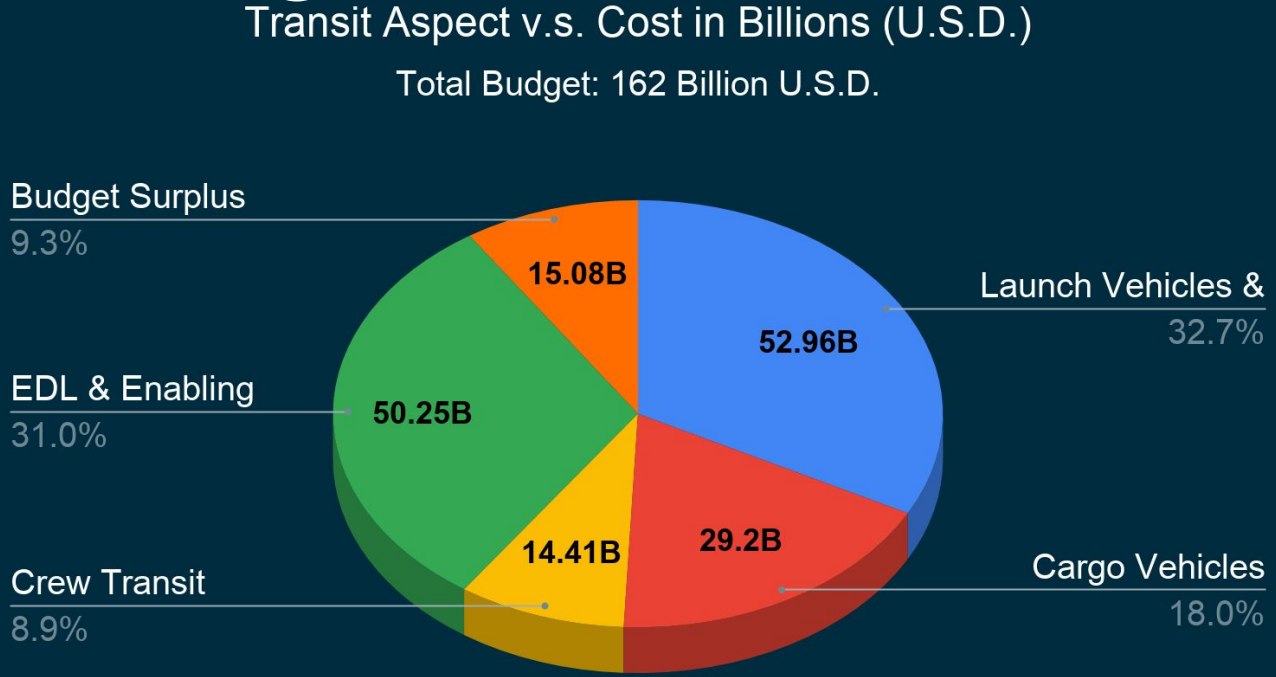
- Cargo Capsule Landing
  - Orbital injection and retro burn to Atmospheric entry
  - Heat Shield + Hypersonic Inflatable Aerodynamic Decelerator (HIAD)
  - Radially positioned engines for suicide burn
  - Cushioned landing

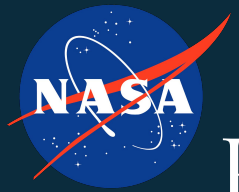
Mars Ascent Vehicle

- Crew SpaceX Starship
  - Refueled through Sabatier Process
    - From Supply Starship
  - Converted into MAV for Crew Return
- Launch Sequence, January 2048
  - Ascends and shifts to 45°, prograde
  - Azimuth 88°
  - Burns 3.6 km/s Δv to escape LMO
  - ~670,000 kg propellant
    - ~528,188 kg LOX
    - ~142,754 kg LM



Cost Budget


Transit Aspect v.s. Cost in Billions (U.S.D.)
Total Budget: 162 Billion U.S.D.
Budget Surplus
9.3%
15.08B
Launch Vehicles &
32.7%
52.96B
EDL & Enabling
31.0%
50.25B
14.41B
29.2B
Crew Transit
8.9%
Cargo Vehicles
18.0%

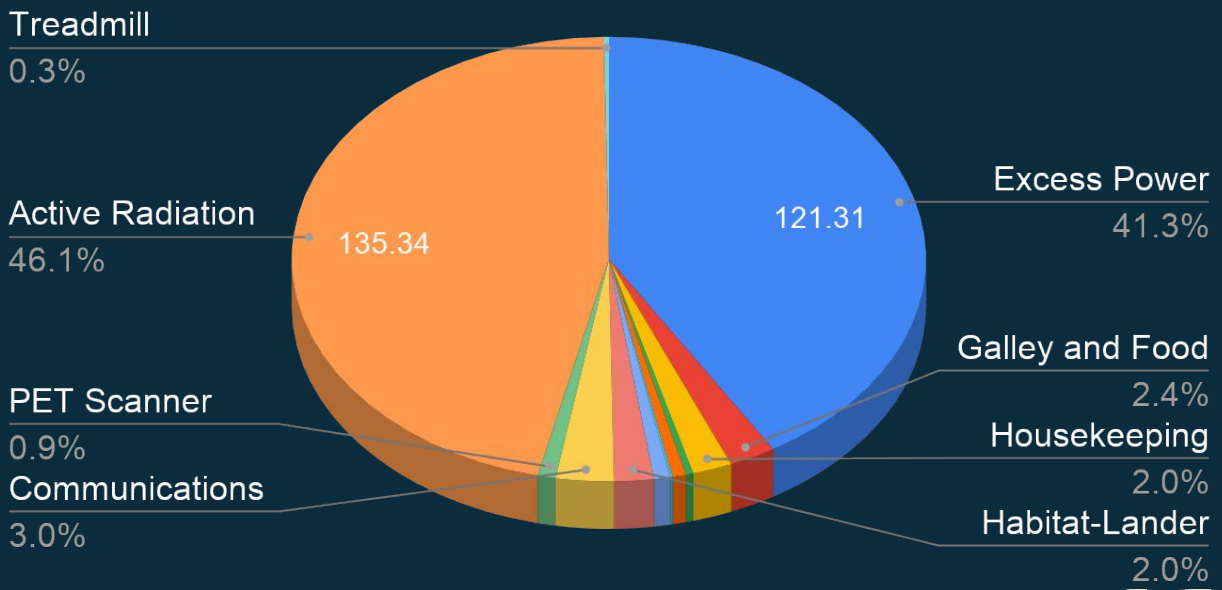


Power Budget

- Power source: Solar
    - Crewed Starship
        - Similar to ISS
    - Cargo Starship and Falcon Heavy I
- Large Capacity Batteries
    - Buffers power systems
        - Not every system is constantly active
    - Power failsafe in case repairs are needed
        - Highest capacity in the Crewed Starship
- Cryocoolers and Thermal Systems to maintain equipment

Power Budget

Total Power Usage of Crew Starship (172.46 kW/293.76 kW)



Radiation

- Electrostatic Active Shielding
    - Like charges repel one another
    - Van De Graaff generator
    - Most effective for Solar Particle Events and Galactic Cosmic Rays
    - Advantageous in the Van Allen Belt

- RXF1 (Polyethylene based material)
    - Crew Cabins
    - Passive Shielding

Risk and Safety

Pre/Post Mitigation

Likelihood					
5					A1
4					B1
3				E1	C1, D1
2				B2	A2
1				E2	C2, D2
	1	2	3	4	5

Consequence

	Pre LxC	Risk	Mitigation	Post LxC
A	(5, 5)	Env.	Cleaning, Redesign, Back-up	(2, 5)
B	(4, 5)	Power	Back-up sources	(2, 4)
C	(3, 5)	Fuel	Before arrival	(1, 5)
D	(3, 5)	EDL	Testing	(1, 5)
E	(3, 4)	Radiation	Protection, Back-up	(1, 4)

Human Safety

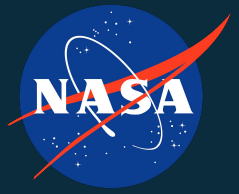
Physical health concerns

- Long term exposure to radiation
- Lack of adequate nutrition
- Harmful effects of microgravity
    - Combated with the ARED

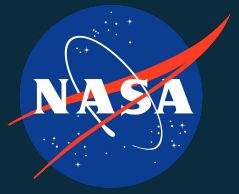
Human Safety

Mental health concerns:

- Extended confinement/isolation
- Boredom
- Trouble sleeping



Thank you!



Any questions?